Chapter 16

ALTERNATING CURRENT

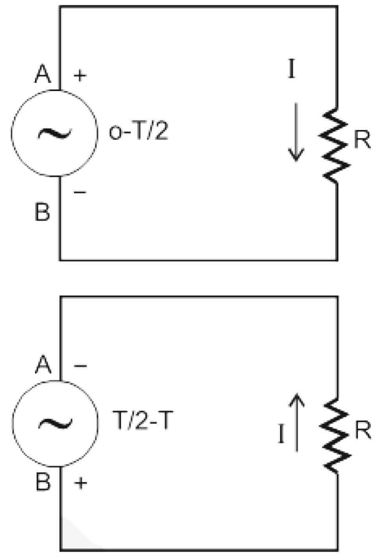
LEARNING OBJECTIVES

At the end of this chapter the students will be able to:

- Understand and describe time period, frequency, the peak and root mean square values of an alternating current and voltage.
- Know and use the relationship for the sinusoidal wave.
- Understand the flow of A.C. trough resistors, capacitors and inductors.
- Understand how phase lags and leads in the circuit.
- Apply the knowledge to calculate the reactances of capacitors and inductors.
- Describe impedance as vector summation of resistances.
- Know and use the formulae of A.C. power to solve the problems.
- Understand the function of resonant circuits.
- Appreciate the principle of metal detectors used for security checks.
- Describe the three phase A.C. supply.
- Know the production, transmission and reception of electromagnetic waves.

Q.1 Define alternating current. Also explain time period and waveform of alternating current.

Ans. **ALTERNATING CURRENT**



Alternating current (A.C) is that which is produced by a voltage source whose polarity keeps on reversing with time.

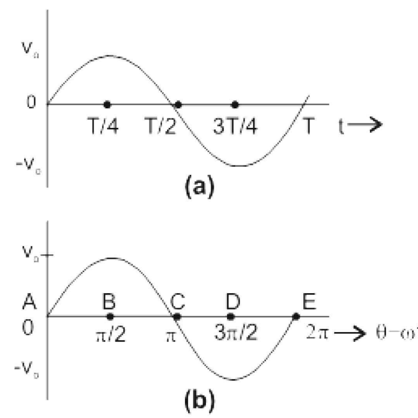
Here the terminal A of the source is positive with respect to terminal B and it remains so during a time interval O to T/2. At T/2 the terminals change their polarity such that A becomes negative and B positive during time T/2 – T. As a result of this change of polarity the direction of current flow in the circuit also changes.

Time Period

The time interval 'T' during which the voltage source changes its polarity once is known as period T of alternating current or voltage. The relation between frequency 'f' and time period 'T' is given as

$$f = \frac{1}{T}$$

Waveform of Alternating Voltage



The most common source of alternating voltage is an A.C generator which has been described such that the output voltage V of A.C generator at any instant is given by

$$V = V_o \sin \omega t$$

$$= V_o \sin \frac{2\pi}{T} \times t$$

Here T is the period of rotation of coil of generator and V_o be maximum value of voltage. V changes with time 't'.

To draw the graph we take the values of V with time t in the following

(i) At $t = 0 \Rightarrow$

$$V = V_o \sin \frac{2\pi}{T} = V_o \sin 0^\circ$$

$$V = V_o \times 0 = 0 \qquad \because \sin 0^\circ = 0$$

(ii) At $t = T/4 \Rightarrow$

$$V = V_o \sin \frac{2\pi}{T} \times \frac{T}{4}$$

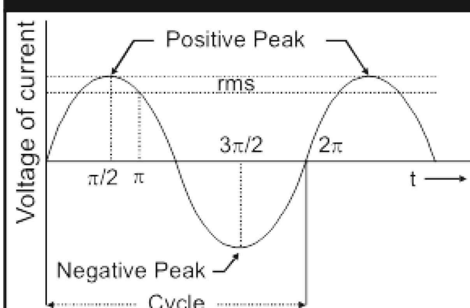
$$= V_o \sin \frac{\pi}{2} = V_o \times 1 \qquad \because \sin \frac{\pi}{2} = 1$$

$$V = V_o$$

(iii) At $t = T/2 \Rightarrow$

$$V = V_o \sin \frac{2\pi}{T} \times \frac{T}{2}$$

Do You Know?



$V_{rms} = 0.7\,V_o$

$I_{rms} = 0.7\,I_o$

$$= V_o \sin \pi \quad = V_o \times 0 \quad \because \sin \pi = 0$$

$$V = 0$$

(iv) At t = 3T/4 ⇒

$$V = V_o \sin \frac{2\pi}{T} \times \frac{3T}{4}$$

$$= V_o \sin \frac{3\pi}{2} = V_o \times -1 \because \sin \frac{3\pi}{2} = -1$$

$$V = -V_o$$

(v) At t = T ⇒

$$V = V_o \sin \frac{2\pi}{T} \times T$$

$$= V_o \sin 2\pi = V_o \times 0 \quad \because \sin 2\pi = 0$$

$$V = 0$$

The variation of V with time 't' and angle 'θ' is shown in the figure which is the waveform of alternating voltage which is a sine curve. The output voltage of A.C generator varies sinusoidally.

Note: *The main reason for the world wide use of A.C. is that it can be transmitted to long distance and at a very low cost.*

Instantaneous Value

The value of voltage or current that exists in a circuit at any instant of time 't' measured from some reference point is known as its instantaneous value.

$$V = V_o \sin \omega t$$

$$= V_o \sin \frac{2\pi}{T} \times t$$

$$= V_o \sin 2\pi ft$$

Peak Value

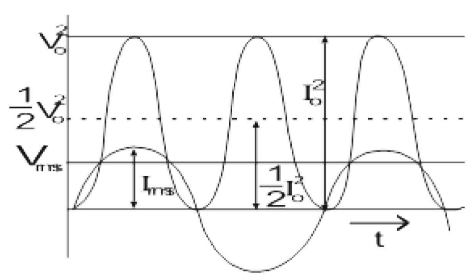
It is the highest value reached by the voltage or current in one cycle. It is denoted by V_o.

Peak to Peak Value

The sum of the positive and negative peak values (p-p) known as peak to peak value of voltage from figure it is '$2V_o$'.

Q.2 What is the root mean square value of alternating current?

Ans. ROOT MEAN SQUARE (rms) VALUE



If we connect an ordinary D.C. ammeter to measure A.C. it would measure its value as average over a cycle. The average value of A.C. current and voltage over a cycle is zero, but the power delivered during a cycle is not zero because power is I^2R and value of I^2 is positive even for negative value of 'I'. The average value of I^2 is not zero and is called the mean square current. The alternating current or voltage is actually measured by square root of its mean square value known as "root mean square (rms) value".

Its expression is written as

$$V_{rms} = \sqrt{\frac{V_o^2}{2}} = \frac{V_o}{\sqrt{2}} = 0.7\ V_o$$

Similarly,

$$I_{rms} = \sqrt{\frac{I_o^2}{2}} = \frac{I_o}{\sqrt{2}} = 0.7\ I_o$$

Most of the alternating current and voltage maters are calibrated to rest rms values.

Q.3 Define phase of A.C.

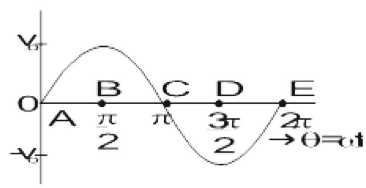
Ans. **PHASE OF A.C.**

The relation for the instantaneous value of alternating voltage is given by

$$V = V_o \sin \omega t$$

$$= V_o \sin \theta$$

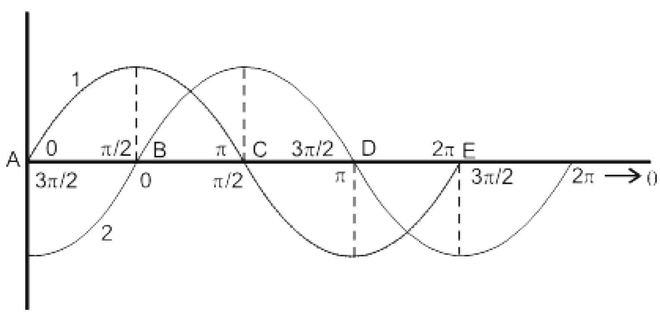
Here angle 'θ' which specifies the instantaneous value of the alternating voltage or current is known as its phase.

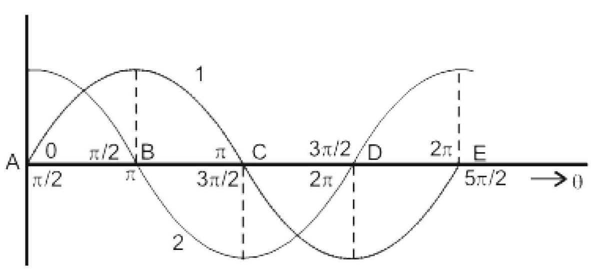


Here the phase at the points A, B, C, D and E in the figure is 0, $\pi/2$, π, $3\pi/2$ and 2π respectively.

Q.4 Define phase lag and phase head.

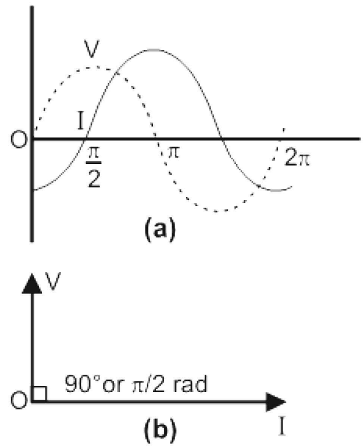
Ans. **PHASE LAG AND PHASE LEAD**





In practice, the phase difference between two alternating quantities is more important than their absolute phases. Figure shows two waveforms 1 and 2. The phase angles of the waveform 1 at the points A, B, C, D and E have been shown above the axis and those of waveform 2 below the axis. At the point B, the phase of 1 is $\pi/2$ and that of 2 is 0. Similarly it can be seen that at each point the phase of waveform 2 is less than the phase of waveform 1 by an angle of $\pi/2$. We say that A.C 2 is lagging behind A.C 1 by an angle of $\pi/2$. It means that at each instant, the phase of A.C 2 is less than the phase of A.C 1 by $\pi/2$. Similarly it can be seen in figure, that the phase at each point of the waveform of A.C 2 is greater than that of waveform 1 by an angle $\pi/2$. In this case, it is said that A.C 2 is leading the A.C 1 by $\pi/2$. It means that at each instant of time, the phase of A.C 2 is greater than that of 1 by $\pi/2$.

Vector Representation of an Alternating Quantity



A sinusoidally alternating voltage or current can be graphically represented by a counter clockwise rotating vector provided it satisfies the following conditions:

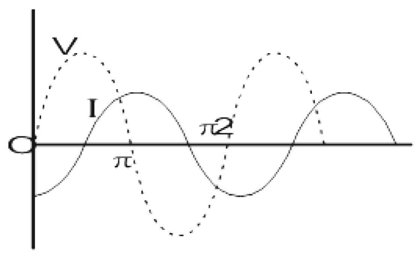
(i) Its length on a certain scale represents the peak or rms value of the alternating quantity.

(ii) It is in the horizontal position at the instant when the alternating quantity is zero and is increasing positively.

(iii) The angular frequency of the rotating vector is the same as the angular frequency ω of the alternating quantity.

Figure (a) shows a sinusoidal voltage waveform leading an alternating current waveform by $\pi/2$. The same fact has been shown vectorially in figure (b). Here vector **OI** represents the peak or rms value of the current which is taken as the reference quantity. Similarly **OV** represents the rms or peak value of the alternating voltage which is leading the current by 90°. Both vectors are supposed to be rotating in the counter clockwise direction at the angular frequency ω of the two alternating quantities. Figure (b) shows the position of voltage and current vector at t = 0.

A.C. CIRCUITS



The basic circuit element in a D.C. circuit is a resistor (R) which controls the current or voltage and the relationship between them is given by Ohm's law that is V = IR.

In A.C. circuits, in addition to resistor R, two new circuit elements namely INDUCTOR (L), and CAPACITOR (C) become relevant. The current and voltages in A.C. circuits are controlled by three elements R, L and C. We would study the response of an A.C circuit when it is excited by an alternating voltage.

Q.5 Describe A.C through a resistor.

Ans. A.C. THROUGH A RESISTOR

Here a resistor 'R' is connected with A.C. source. The potential difference across the terminals A and B of resistor at any time 't' will be

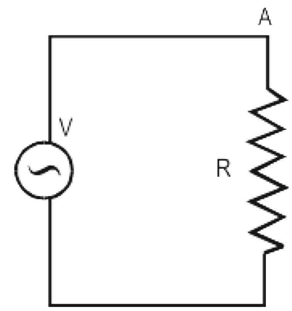
$$V = V_o \sin \omega t$$

where 'V_o' be the peak value of alternating voltage. The current 'I' flowing through the resistor is given by ohm's law

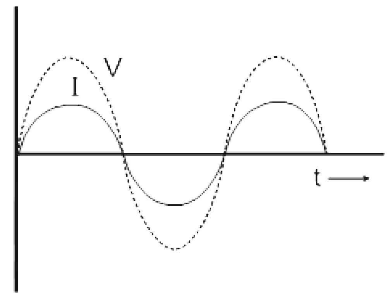
$$I = \frac{V_o}{R} \sin \omega t$$

$$I = I_o \sin \omega t$$

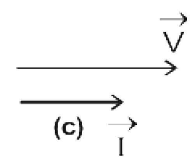
where 'I is instantaneous value and I_o the peak value. The voltage and current both are sine functions which vary with time. It means when voltage rises the current also rises, both pass the maximum and minimum values at the same instant. In purely resistive A.C. circuit instantaneous values of voltage and current are in phase. This behaviour is shown graphically in figure.



(a)



(b)



(c)

Also $\vec{V}$ and $\vec{I}$ vectors are drawn parallel because there is no phase different between them. The instantaneous power in the resistance is given as

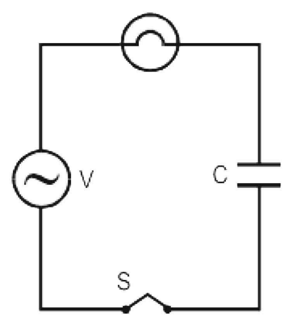
$$P = I^2R$$

or $$P = VI = \frac{V^2}{R}$$

It is very important to noted that this equation holds only when current and voltage are in phase.

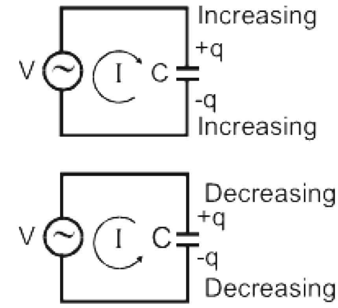
Q.6 Describe A.C. through a capacitor.

Ans. A.C. THROUGH A CAPACITOR



Alternating current can flow through a resistor, but it is not obvious that how it can flow through a capacitor. This can be demonstrated by the circuit shown in figure. A low power bulb is connected in series with a 1 μF capacitor to supply mains through a switch. When the switch is closed, the bulb lights up showing that the current is flowing through the capacitor. Direct current cannot flow through a capacitor continuously because of the presence of an insulating medium between the plates of the capacitor. Now let us see how does A.C flows through a capacitor. The current flows because the capacitor plates are continuously charged, discharged and charged the other way round by the alternating voltage (Figure a). The basic relation between the charge q on a capacitor and the voltage V across its plates i.e., q = CV holds at every instant. If $V = V_o \sin \omega t$ is the applied alternating voltage, the charge on the capacitor at any instant will be given by

$$q = CV = CV_o \sin \omega t \quad \ldots\ldots (1)$$



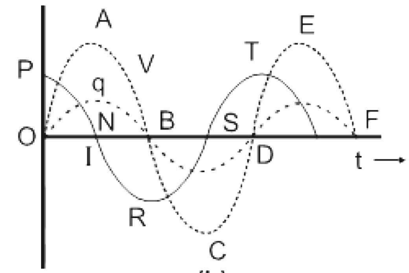
(a)

Since C, V_o are constants, it is obvious that q will vary the same way as applied voltage i.e., V and q are in phase (Figure b).

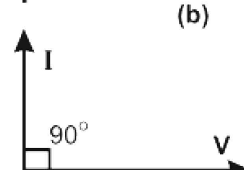
The current I is the rate of change of θ with time i.e.,

$$I = \frac{\Delta q}{\Delta t}$$

So the value of I at any instant is the corresponding slope of the q – t curve. At O when q = 0, the slope is maximum, so I is then a maximum. From O to A, slope of the q – t curve decreases to zero. So I is zero at N. From A to B the slope of the q – t curve is negative and so I is negative from N to R. In this way the curve PNRST gives the variation of current with time.



(b)



(c)

Referring to the figure (b) it can be seen that the phase at O is zero and the phase at the upper maximum is π/2. So in figure (b) the phase of V at O is zero but the current at this point is maximum so its phase is π/2. Thus, the current is leading the applied voltage by 90° or π/2. Now consider the points A and N. The phase of alternating voltage at A is π/2 but the phase of current at N is π. Again the current is leading the voltage by 90° or π/2. Similarly by comparing the phase at the pair of points (B, R), (C, S) and (D, T) it can be seen that at all these points the current leads the voltage by 90° or π/2. This is vectorially represented in figure (c).

Reactance of a capacitor is a measure of the opposition offered by the capacitor to the flow of A.C. It is usually represented by X_C. Its value is given by

$$X_C = \frac{V_{rms}}{I_{rms}} \quad \ldots\ldots (2)$$

where V_{rms} is the rms value of the alternating voltage across the capacitor and I_{rms} is the rms value of current passing through the capacitor. The unit of reactance is ohm. In case of capacitor

$$X_C = \frac{1}{2\pi fC} = \frac{1}{\omega C} \quad \ldots\ldots (3)$$

According to eq. (3), a certain capacitor will have a large reactance at low frequency. So the magnitude of the opposition offered by it will be large and the current in the circuit will be small. On the other hand at high frequency, the reactance will be low and the high frequency current through the same capacitor will be large.

Q.7 Define reactance of a capacitor.

Ans. REACTANCE OF CAPACITOR

It is the measure of the opposition offered by the capacitor to the flow of A.C. It is denoted by "X_C".

$$X_C = \frac{V_{rms}}{I_{rms}}$$

where V_{rms} is rms value of the alternating voltage across the capacitor and I_{rms} is the rms value of current passing through the capacitor.

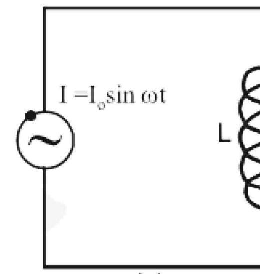
$$X_C = \frac{1}{2\pi fC} = \frac{1}{\omega C}$$

The unit of reactance is ohm (Ω).

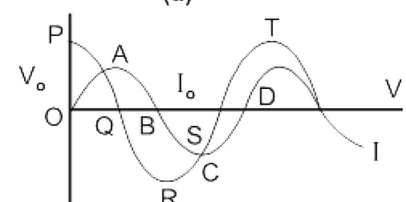
At low frequency the reactance will be high and current through the capacitor will be lower. On the other hand at high frequency the reactance will be low.

Q.8 Describe A.C. through an inductor.

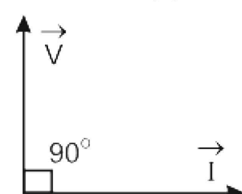
Ans. A.C. THROUGH AN INDUCTOR



(a)



(b)



(c)

An inductor is usually in the form of a coil or a solenoid wound from a thick wire so that it has a large value of self inductance and has a negligible resistance. We have already seen how self inductance opposes changes of current. So when an alternating source of voltage is applied across an inductor, it must oppose the flow of A.C which is continuously changing figure. Let us assume that the resistance of the coil is negligible. We can simplify the theory by considering first, the current and then finding the potential difference across the inductor which will cause this current. Suppose the current is $I = I_o \sin 2\pi ft$. If L is the inductance of the coil, the changing current sets up a back emf in the coil of magnitude.

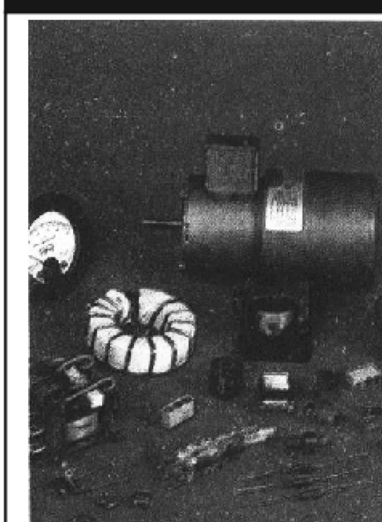
$$\varepsilon_L = L\frac{\Delta I}{\Delta t}$$

To maintain the current, the applied voltage must be equal to the back e.m.f. The applied voltage across the coil must, therefore, be equal to

$$V = L\frac{\Delta I}{\Delta t}$$

Since L is a constant, V is proportional to $\frac{\Delta I}{\Delta t}$. Figure (b) shows how the current I varies with time. The value of ΔI/Δt is given by the slope of the I – t curve at the various instants of time. At O, the value of the slope is maximum, so the maximum value of V equal to V_o occurs at O and is represented by OP (Figure b). From O to A the slope of I – t graph decreases to zero so the voltage decreases form V_o to zero at Q. From A to B, the slope of the I – t graph is negative, so the voltage curve goes from Q to R. In this way the voltage is represented by the curve PQRST corresponding to current curve OABCD. By comparing the phases of the pair of points (O, P), (A, Q), (B, R), (C, S) and (D, T), it can be seen that the phase of the current is always less than the phase of voltage by 90° or π/2 i.e., current lags behind the applied voltage by 90° or π/2 or the applied voltage leads the current by 90° or π/2. This is vectorially shown in figure (c) inductive reactance is a measure of the opposition offered by the inductance coil to the flow of A.C. It is usually denoted by X_L.

Do You Know?



Inductors are made in many sizes to perform a wide variety of functions in business and industry.

$$X_L = \frac{V_{rms}}{I_{rms}} \qquad \ldots\ldots (1)$$

If V_{rms} is rms value of the alternating voltage across an inductance and I_{rms}, the rms value of the current passing through it, he the value of X_L is given by

$$X_L = \frac{V_{rms}}{I_{rms}} = 2\pi fL = \omega L \qquad \ldots\ldots (2)$$

The reactance of a coil, therefore, depends upon the frequency of the A.C and the inductance L. It is directly proportional to both f and L. L is expressed in henry, f in hertz and X_L in ohms. It is to be noted that inductance and capacitance behave oppositely as a function of frequency. If f is low X_L is small but X_C is large. For high f, X_L is large but X_C is small. The behaviour of resistance is independent of frequency.

Power Dissipation in Inductor

No power is dissipated in a pure inductor. In first quarter of cycle both V and I are positive so power is positive which means the energy is supplied to inductor. In the second quarter V is –ve but I is +ve so the power is negative and energy is returned by the inductor. Again in third quarter, it receiving energy but returns the same amount in fourth quarter. In this way no net change of energy is observed in a cycle. Since an inductor coil does not consume energy the coil is used for controlling A.C. without consumption of energy, such as inductance coil is known as choke.

Q.9 Define inductive reactance.

Ans. **INDUCTIVE REACTANCE**

It is the measure of the opposition offered by the inductance coil to the flow of A.C. It is denoted by "X_L".

$$X_L = \frac{V_{rms}}{I_{rms}}$$

or $$X_L = 2\pi fL = \omega L$$

The reactance of coil depends upon the frequency 'f' of A.C source. It is directly proportional to 'L' and 'f' its unit is ohm (Ω). It is noted that inductance and capacitance behave oppositely as a function of frequency.

Q.10 Define impedance. Find its value for R.C series circuit and explain with phase or diagram.

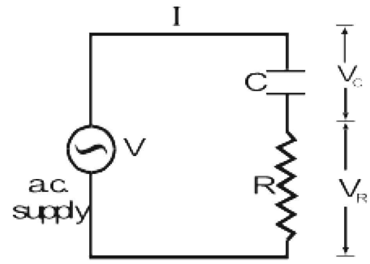
Ans. **IMPEDANCE**

The resistance (R), inductance (L) and capacitance (C) offer opposition to flow of A.C which is measured by resistance R and reactances X_L and X_C. If a circuit consists of all these elements then "the combined effect of resistance and reactances in such circuit is known as impedance". It is denoted by 'Z'.

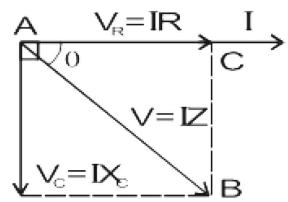
$$Z = \frac{V_{rms}}{I_{rms}}$$

Its unit is ohm (Ω).

R.C SERIES CIRCUIT



There is a circuit in which a resistance 'R' and capacitor 'C' are connected in series with A.C source. The same current flows through R and C due to series combination. If I_{rms} is the value of current then potential difference across 'R' will be $V_R = I_{rms}R$ and it would be in phase with current. Similarly the potential difference across capacitor is $V_C = I_{rms}X_C$ the voltage lags the current by 90°. It is shown in the diagram. The applied voltage V_{rms} is obtained by resultant vector. Considering ΔABC



$$V_{rms} = \sqrt{V_R^2 + V_C^2}$$

$$= \sqrt{(I_{rms}R)^2 + \left(\frac{I_{rms}}{\omega C}\right)^2}$$

$$= I_{rms}\sqrt{R^2 + \left(\frac{1}{\omega C}\right)^2}$$

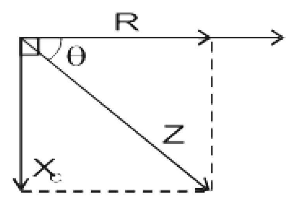
$$\frac{V_{rms}}{I_{rms}} = \sqrt{R^2 + \left(\frac{1}{\omega C}\right)^2}$$

$$\text{(Impedance) } Z = \sqrt{R^2 + \left(\frac{1}{\omega C}\right)^2}$$

This shows that current leads the applied voltage by an angle 'θ'.

$$\theta = \tan^{-1}\left(\frac{X_C}{R}\right)$$

$$= \tan^{-1}\left(\frac{1}{\omega CR}\right)$$



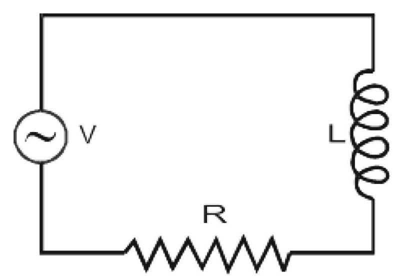
Vector Representation

Here it is known as impedance diagram of circuit. The angle gives the phase difference between the voltage and current.

Q.11 Explain R.L series circuit.

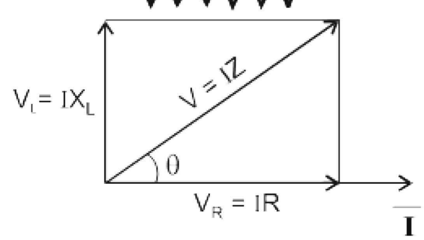
Ans.

R.L SERIES CIRCUIT



There is a resistor 'R' and inductor (L) connected in series with A.C source. We can calculate the impedance of R-L circuit by drawing the impedance diagram. The resistance 'R' is drawn along horizontal line because potential drop $V = I_{rms}R$ is in phase with current. The potential across inductance is $V_L = I_{rms}X_L$ it leads current by 90° so it is perpendicular to 'R' line.

The impedance (Z) of circuit is obtained by vector sum of R and ωL lines.



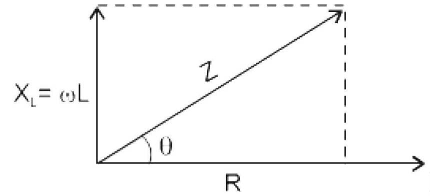
$$Z = \sqrt{R^2 + X_L^2}$$

$$Z = \sqrt{R^2 + (\omega L)^2}$$

The phase difference between the voltage and current is given by angle 'θ'.

$$\theta = \tan^{-1}\left(\frac{X_L}{R}\right)$$

$$= \tan^{-1}\left(\frac{\omega L}{R}\right)$$



POWER IN A.C. CIRCUITS

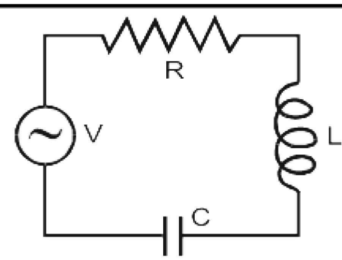
The expression for power $P = V_{rms}I_{rms}$ is true in case of A.C. circuits only when V and I are in phase. The power dissipation in a pure inductive and pure capacitive circuit is zero. In these cases the current lags or leads the applied voltage by 90° and component of applied voltage $\vec{V}$ along the current vector is zero. In A.C. circuits the phase difference between applied voltage V and current I_{rms} is given by 'θ'. From figures of R-C and R-L series circuit it is clear that component of $\vec{V}$ along I is V cos θ. Actually it is this component of voltage vector which is in phase with current. So the power dissipation in A.C. circuit is given as

$$P = I_{rms} \times V_{rms} \cos\theta$$

Here factor "cos θ" is known as power factor.

Q.12 Explain series resonance circuit also discuss its properties.

Ans. **SERIES RESONANCE CIRCUIT (R-L-C)**



(a)

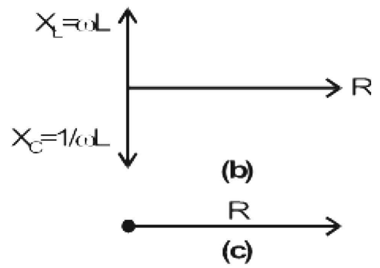
Consider a R-L-C series circuit which is excited by an alternating voltage source whose frequency could be varied (Fig. a). The impedance diagram of the circuit is shown in (Fig. b). As explained earlier, the inductive reactance $X_L = \omega L$ and capacitor reactance $X_C = \frac{1}{\omega C}$ are directed opposite to each other. When the frequency of A.C. source is very small $X_C = \frac{1}{\omega C}$ is much greater than $X_L = \omega L$. So the capacitance dominates at low frequencies and the circuit behaves like an R-C circuit. At high frequencies $X_L = \omega L$ is much greater than $X_C = \frac{1}{\omega C}$. In this case the inductance dominates and the circuit behaves like R-L circuit. In between these frequencies there will be a frequency ω_r at which $X_L = X_C$. This condition is called resonance. Thus at resonance the inductive reactance being equal and opposite to capacitor reactance, cancel each other and the impedance diagram assumes the form (Fig. c). The value of the resonance frequency can be obtained by putting

$$\omega_r L = \frac{1}{\omega_r C}$$

or $$\omega_r^2 = \frac{1}{LC} \quad \text{or} \quad \omega_r = \frac{1}{\sqrt{LC}}$$

or $$f = \frac{1}{2\pi\sqrt{LC}}$$

Resonance Frequency



There is a certain frequency at which $X_L = X_C$ this condition is called resonance. At resonance the inductive reactance being equal and opposite to capacitive reactance cancel the effect of each other and circuit behaves like resistive circuit. The resonance frequency can be calculated as

$$X_L = X_C$$

$$\omega L = \frac{1}{\omega C}$$

$$\omega^2 = \frac{1}{LC}$$

$$\omega = \frac{1}{\sqrt{LC}}$$

$$2\pi f_r = \frac{1}{\sqrt{LC}}$$

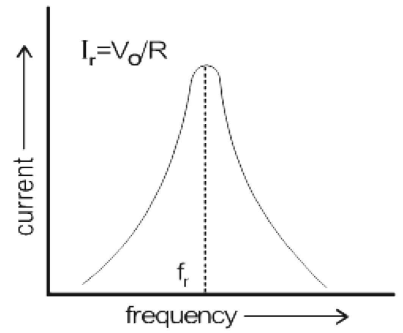
$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

This is the expression for resonance frequency "f_r".

Properties of Series Resonance Circuit

(i) The resonance frequency is given by

$$f_r = \frac{1}{2\pi\sqrt{LC}}$$



(ii) The impedance of circuit at resonance is resistive so current and voltage are in phase and power factor is one.

(iii) The impedance of the circuit is minimum at this frequency and it is equal to 'R'.

(iv) If the amplitude of the source voltage 'V_o' is constant then current is will be maximum at resonance frequency.

(v) At resonance V_L the voltage drop across inductance and V_C the voltage drop across capacitance may be larger than the source voltage.

R-L-C series circuit also called acceptor circuit.

Q.13 What is parallel resonance circuit? Describe its properties. Also find the resonance frequency for the circuit.

Ans.

PARALLEL RESONANCE CIRCUIT

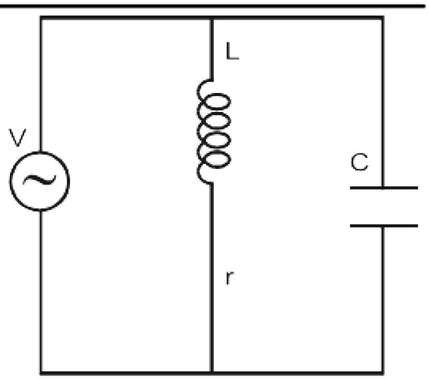


Figure shows a RLC parallel circuit connected with alternating source of voltage whose frequency could be varied. The resistance of coil is very small and capacitor draws a leading current whereas the coil draws a lagging current. The circuit resonate at a frequency which makes $X_L = X_C$ so that the two branch currents are equal but opposite. Hence they cancel out with the result that the current drawn from supply is zero. In actual practice, the current is not zero but has a minimum value due to small resistance r of the coil, the current flowing through r is V/r. Hence energy is needed from supply and energy is dissipated from circuit in the form of heat.

At resonance $X_L = X_C$

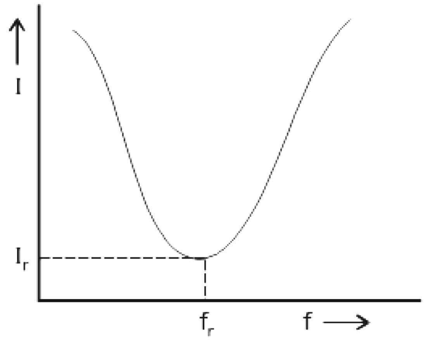
$$I = I_L - I_C = 0$$

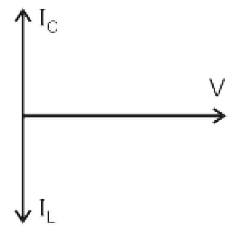
$$\therefore \quad I_L = I_C$$

$$\frac{V}{2\pi f_r L} = V\,2\pi f_r C$$

$$f_r^2 = \frac{1}{4\pi^2 LC}$$

$$f_r = \frac{1}{2\pi\sqrt{LC}}$$





Properties of Parallel Resonant Circuit

(i) The resonance frequency is given by

$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

(ii) At the resonance frequency the circuit impedance is maximum. It is resistive and its value is L/Cr.

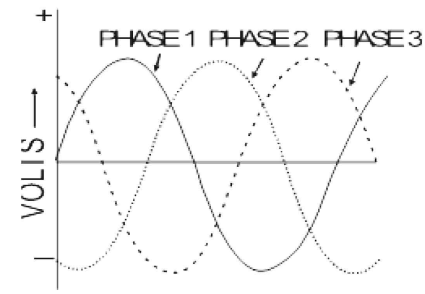
(iii) At resonance the current is minimum and so it is in phase with applied voltage. So power factor is one.

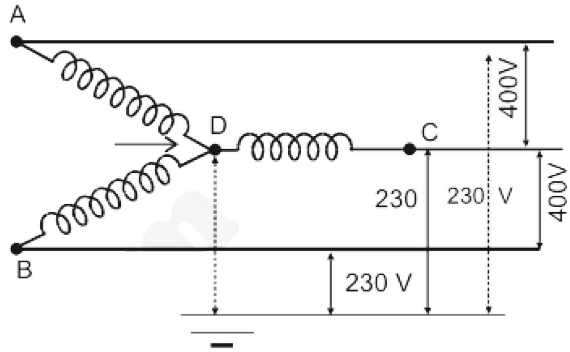
(iv) At resonance the branch currents I_L and I_C may be larger than the source current I. LC parallel circuit is also called as rejecter circuit or tank circuit or oscillator.

Q.14 What is three phase A.C supply?

Ans. THREE PHASE A.C. SUPPLY

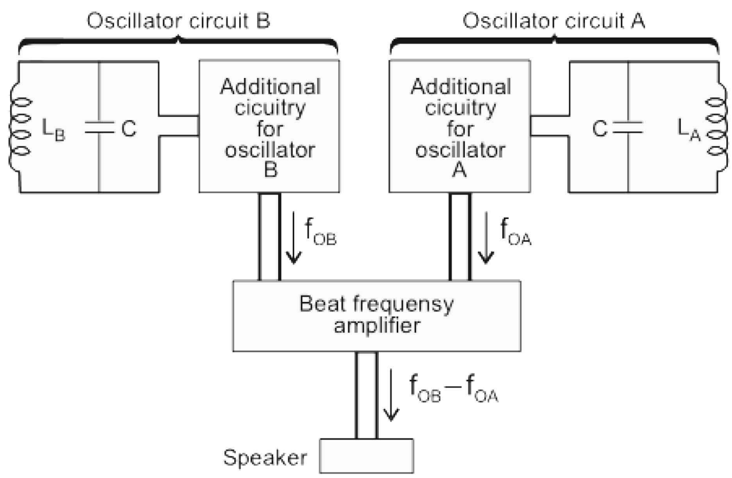
We have already studied that an A.C. generator consists of a coil with a pair of slip rings. As the coil rotates an alternating voltage is generated across the slip rings. In a three phase A.C. generator, instead of one coil, there are three coils inclined at 120° to each other, each connected to its own pair of slip rings. When this combination of three coils rotate in the magnetic field, each coil generates an alternating voltage across its own pair of slip rings. Thus, three alternating voltages are generated. The phase difference between these voltage is 120°. It means that when voltage across the first pair of slip rings is zero, having a phase of 0, the voltage across the second pair of slip rings would not be zero but it will have a phase of 120°. Similarly at this instant the voltage generated across the third pair will have a phase 240°. This is shown in figure. The machine, instead of having six terminals, two for each pair of slip rings, has only four terminals because the starting point of all the three coils has a common junction which is often earthed to the shaft of the generator and the other three ends of the coils are connected to three separate terminals on the machine. These four terminals along with the lines and coils connected to them are shown in figure. The voltage across each of lines connected to terminals A, B, c and the neutral line is 230 V. Because of 120° phase shift, the voltage across any two lines is about 400 V. The main advantage of having a three phase supply is that the total load of the house or a factory is divided in three parts, so that none of the line is over loaded. If heavy load consisting of a number of air conditioners and motors etc., is supplied power from a single phase supply, its voltage is likely to drop at full load. Moreover, the three phase supply also provides 400 V which can be used to operate some special appliances requiring 400 V for their operation.





Q.15 Describe the principle of metal detectors.

Ans. PRINCIPLE OF METAL DETECTORS



A coil and a capacitor are electrical components which together can produce oscillations of current. An L-C circuit behaves just like an oscillating mass – spring system. In this case energy oscillates between a capacitor and an inductor. The circuit is called an electrical oscillator. Two such oscillators A and B are used in the operation of a common type of metal detector in the absence of any nearby metal object, the inductances L_A and L_B are the same and hence the resonance frequency of the two circuits is also same. When the inductor B; called the search coil comes near a metal object, its inductance L_B decreases and corresponding oscillator frequency increases and thus a beat note is heard in the attached speaker. Such detectors are extensively used not only for various security checks but also to locate buried metal objects.

Q.16 Define choke.

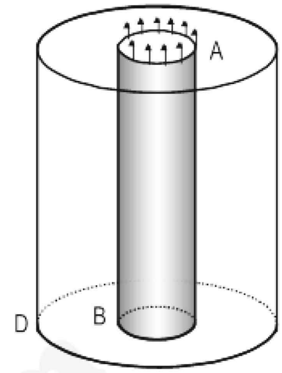
Ans. CHOKE

It is a coil which consists of thick copper wire wound closely in a large number of turns over a soft iron laminated cores. This makes the inductance L of the coil quite large whereas its resistance R is very small. Thus it consumes extremely small power. It is used in A.C. circuits to limit current with extremely small wastage of energy as compared to a resistance or a rheostat.

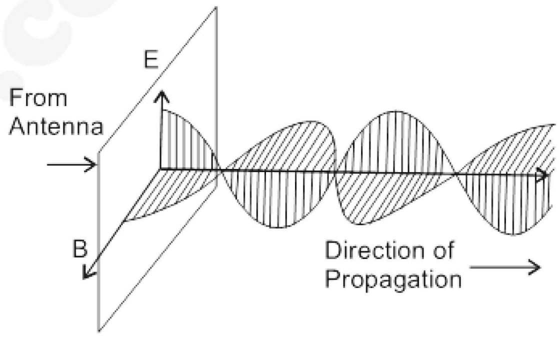
Q.17 What are the electromagnetic waves?

Ans. ELECTROMAGNETIC WAVES

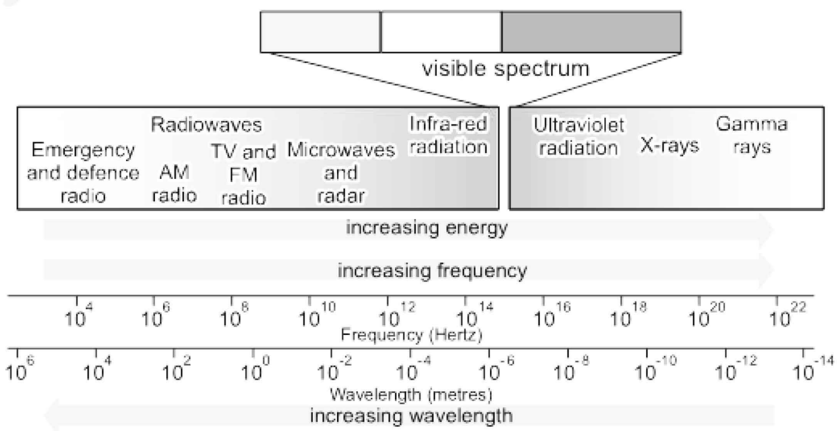
It is a very important class of waves which requires no medium for transmission and which rapidly propagates through vacuum.



In 1864 British physicist James Clark Maxwell formulated a set of equations known as Maxwell's equations which explained the various electromagnetic phenomena. According to these equations, a changing magnetic flux creates an electric field and a changing magnetic flux creates an electric field and a changing electric flux is taking place through it. This changing magnetic flux will set up a changing electric flux in the surrounding region. The creation of electric field in the region CD will cause a change of electric flux through it due to which a magnetic field would be set up in the space surrounding CD and so on. Thus each field generates the other and the whole package of electric and magnetic fields will move along propelling itself through space. Such moving electric and magnetic fields are known as electromagnetic waves. The electric field, magnetic field and the direction of their propagation are mutually orthogonal figure. It can be seen in this figure that the electromagnetic waves are periodic, hence they have a wavelength λ which is given by the relation $c = f\lambda$ where f is the frequency and c is the speed of the wave. In free space the speed of electromagnetic waves is $3 \times 10^{8}\ ms^{-1}$.



Depending upon the values of wavelength and frequency, the electromagnetic waves have been classified into different types of waves as radio waves, microwaves, infrared rays, visible light etc., figure shows the complete spectrum of electromagnetic waves from the low radio waves to high frequency gamma rays.

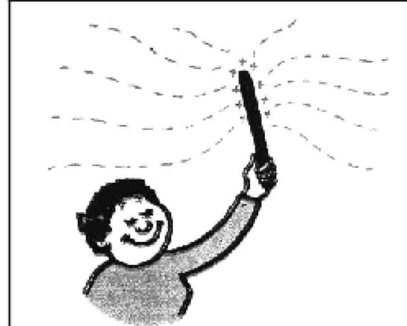


Q.18 Explain the principle of generation, transmission and reception of electromagnetic waves with an example.

Ans. PRINCIPLE OF GENERATION, TRANSMISSION AND RECEPTION OF ELECTROMAGNETIC WAVES

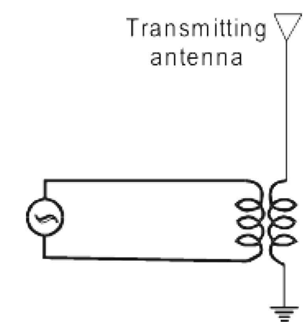
We have seen that electromagnetic waves are generated when electric or magnetic flux is changing through a certain region of space. An electric charge at rest gives rise to a Coulomb's field which does not radiate in space because no change of flux takes place in this type of field. A charge moving with constant velocity is equivalent to a steady current which generates a constant magnetic field in the surrounding space, but such a field also does not radiate out because no changes of magnetic flux are in involved. Thus only chance to generate a wave of moving field is when we accelerate the electric charges.

Tit-bits

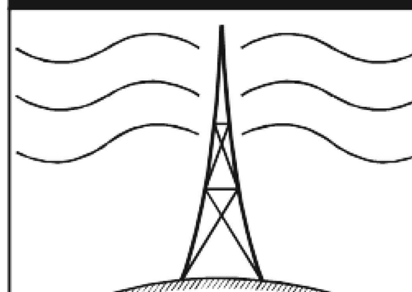


Shake an electrically charged object to and fro, and you produce electromagnet waves.

A radio transmitting antenna provides a good example of generating electromagnetic waves by acceleration of charges. The piece of wire along which charges are made to accelerate is known as transmitting antenna figure. It is charged by an alternating source of potential of frequency f and time period T. As the charging potential alternates, the charge on the antenna also constantly reverses. For example if the top has +q charges at any instant, then after time T/2 the charge on it will be –q. Such regular reversal of charges on the antenna gives rise to an electric flux that constantly changes with frequency f. This changing electric flux sets up an electromagnetic wave which propagates out in space away from the antenna. The frequency with which the fields alternate is always equal to the frequency of the source generating them. These electromagnetic waves which are propagated out in space from antenna of a transmitter are known as radio waves. In fee space these waves travel with the speed of light.

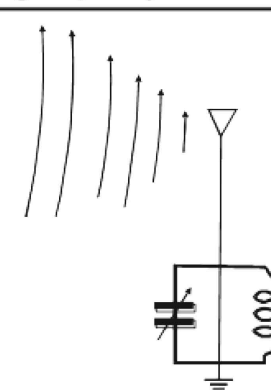


Do You Know?



When electrons in the transmitting antenna vibrate 94,000 times each second, they produced radio waves having frequency 94 kHz.

Suppose these waves impinge on a piece of wire of shown. The electrons in the wire move under the action of the oscillating electric field which give rise to an alternating voltage across the wire. The frequency of this voltage is the same as that of the wave intercepting the wire. The wire receiving the wave is known as receiving antenna. As the electric field of the wave is very weak at a distance of many kilometres from the transmitter, the voltage that appears across the receiving antenna placed in space is usually due to the radio waves of large number of frequencies. The voltage of one particular frequency can be picked up by connecting an inductance L and a variable capacitor C in parallel with one end of the receiving antenna.



If one adjusts in value of the capacitor so that the natural frequency of L-C circuit is the same as that of the transmitting station to be picked up, the circuit will resonate under the driving action of the antenna. Consequently, the L-C circuit will build up a large response to the action of only that radio wave to which it is tuned. In your radio receiver set when you change stations you actually adjust the value of C.

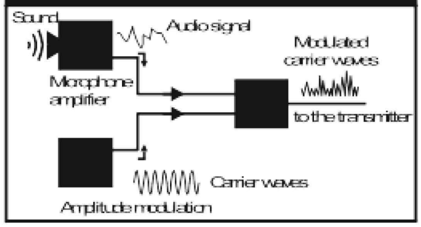
Q.19 Define modulation with its types.

Ans. **MODULATION**

Speech and music etc., are transmitted hundred of kilometres away by a radio transmitter. The scene in from of a television camera is also sent many kilometers away to viewers. In all these uses, the carrier of the programme is a high frequency radio wave. The information i.e., light, sound or other data is impressed on the radio wave and is carried along with it to the destination.

Modulation is the process of combining the low frequency signal with a high frequency radio wave called carrier wave. The resultant wave is called modulated carrier wave. The low frequency signal is known as modulation signal. Modulation is achieved by changing the amplitude or the frequency of the carrier wave in accordance with the modulating signal. Thus we have two types of modulations which are

For Your Information



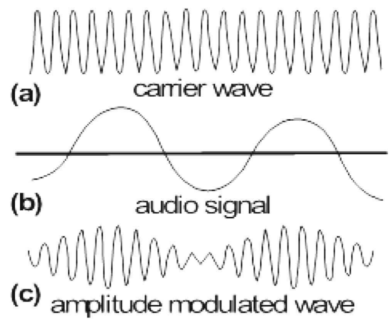
(1) Amplitude modulation (A.M.)

(2) Frequency modulation (F.M.)

Amplitude Modulation

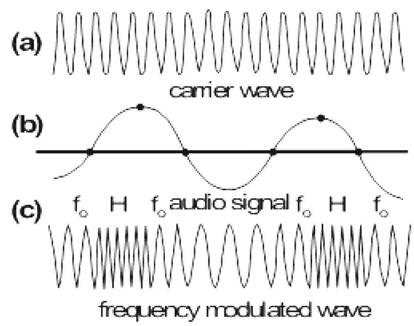
In this type of modulation the amplitude of the carrier wave is increased or diminished as the amplitude of the superposing modulating signal increases and decreases.

Figure (a) represents a high frequency carrier wave of constant amplitude and frequency. Figure (b) represents a low or audio frequency signal of a sine waveform. Figure (c) shows the result obtained by modulating the carrier waves with the modulating wave. The A.M. transmission frequencies range from 540 kHz to 1600 kHz.



Frequency Modulation

In this type of modulation the frequency of the carrier wave is increased or diminished as the modulating signal amplitude increases or decreases but the carrier wave amplitude remains constant. Figure shows frequency modulation. The frequency of the modulated carrier wave is highest (point H) when the signal amplitude is at its maximum positive value and is at its lowest frequency (point L) when signal amplitude has maximum negative. When the signal amplitude is zero, the carrier frequency is at its normal frequency f_o.



The F.M. transmission frequencies are much higher and ranges between 88 MHz to 108 MHz. F.M. radio waves are affected less by electrical interference than A.M. radio waves and hence, provide a higher quality transmission of sound. However, they have a shorter range than A.M. waves and are less able to travel around obstacles such as hills and large buildings.